9

STRIPPED ZONES AT CLIFF EDGES ALONG A HIGH WAVE ENERGY COAST, PORT CAMPBELL, VICTORIA

By George Baker

[Read 12 December 1957]

Abstract

Stripped zones, which vary from a few feet to approximately sixty yards wide according to cliff height, have been produced, by storm action, at the edges of the tops of marine cliffs cut in soft Miocene limestone, and are marked features of the high wave energy karst coast of the Port Campbell district.

They are best developed in positions most exposed to frontal wave attack where relatively deep water occurs at cliff bases. Stripping away of materials forming a thin veneer to the Miocene limestone at cliff edges, is accomplished by storm waves, aided by surface run-off of rain-waters, and to a lesser extent, wind action.

The local geomorphology of the stripped zones is dominated by small-scale, but prominent, features such as protruding accretionary growth structures, basin-like depressions, small sink-holes, and, at the seaward edges of the stripped cliff-tops, solution-abrasion pipes.

Introduction

Stripped zones are relatively common at the edges of the tops of steep, high, marine cliffs cut in Tertiary (Miocene) aphanitic limestone in the Port Campbell district, south coast of western Victoria. They are best developed at the seaward edges of the cliff-tops in marine environments where attack by on-shore wave systems is most strong. High energy wave attack is here influenced by a long fetch of several thousand miles, and is largely controlled by southwesterlies as the major wind resultant. Surface run-off of rain-water in a region subject to relatively frequent coastal showers and occasional severe storms, assists and subsequently becomes an important factor in removing superficial materials from the edges of vertical cliffs.

The stripped zones are marked features of several short stretches of this high energy karst coastline, extending along the edges of the cliff-tops for distances of from tens of yards to over 400 yds. They are most pronounced at such exposed portions of the coastline as Point Hesse, Gravel Point, the Amphitheatre, Broken Head and environs, and the seaward ends of smaller promontories in the region of Loch Ard Gorge (see Baker, 1943, p. 362, Fig. 3). These are positions where relatively deep water occurs right up to the cliff bases, so that wave attack is unimpeded by cliff talus, or by shore platforms or by sandy and pebbly beaches; wave energy is thus at a maximum for such parts of the coastline. Storm waves are able to break high up directly on to cliff faces, well above the visor zone, and significant amounts of large masses and clumps of spray are frequently tossed up on to the edges of cliff-tops. Where protecting features occur at cliff bases, or in more sheltered positions where cliffs trend normal to the wave front and wave energy is moderated, or whereever cliff height is too great, stripped zones are absent from the cliff-tops.

Agents Producing the Stripped Zones

Stripped zones result where the action of tossed-up clumps of sea-spray and rain-waters combine to remove vegetation, soils, subsoils and Post-Miocene Clays from the edges of the cliff-tops, thereby exposing the more or less horizontally bedded Port Campbell Limestone (Miocene), with its abundant content in places of calcareous accretionary growths. Along the edges of such cliff-tops, the effects of erosion are dominant over those of deposition; the matrix of the Port Campbell Limestone is more prone to rapid weathering, and the accretionary growth structures become exposed as prominent, if relatively small-scale projecting features in the local geomorphology (Pls. XXVII and XXVIII).

The width of the stripped zone landwards from cliff edges, is largely controlled by cliff height. The widest, which are some 60 to 70 yds. across and rarely wider, occur where cliff-tops are 10 ft. and up to 60 ft. above normal tide level, for here, the stripped zones are within the range of attack by average storm waves striking vertical to backward sloping steep cliffs at the right angle. At the edges of cliffs rising 60 to 200 ft. above normal tide level, stripped zones dwindle to a few feet in width, and are only occasionally attacked under the most severe gales (south-westerlies). Edges of cliffs above 200 ft. high, do not possess stripped zones; their seaward edges are marked by small bevels caused by partial soil-slip.

Nature of Exposed Surfaces

The surfaces of the stripped zones are seldom horizontal despite the horizontally-bedded nature of the limestone; they usually have a gentle seaward slope produced by subaerial erosion. Smooth undulations of the surface characterize the landward regions of examples up to 50 or 60 ft. above sea level, while towards their seaward edges, where accretions and accretionary growth layers are better exposed (Pl. XXVII, fig. A), the surface is invariably ragged and craggy. Such surfaces are principally swept free of all loose materials except for the very coarsest of rock rubble, which sometimes remains strewn over parts of the stripped zones, or is more often concentrated along the rather more steeply sloping landward fringe, just below the zone of soil and vegetation. Broader stripped zones situated nearer sea level (i.e. some 10 to 20 ft. high), usually have much pitted surfaces, especially near their seaward edges. The pitting sometimes assumes a relatively regular cellular pattern, and parts of the surface have been eroded along prominent joint planes, other parts carry a number of rock pools of varying depth and diameter, while the only rock debris present consists of large boulders on the surface of the stripped zone, smaller grinder pebbles and cobbles in the rock pools. Landward from the pitted regions, the surfaces become much smoother.

Processes Operating on Exposed Surfaces

After removal of the veneer of vegetation, soil, subsoil and Post-Miocene Clay by mechanical processes in the initial phases, the exposed portions of the Port Campbell Limestone constituting the surface of the stripped zones, become subjected to weathering in various ways. The factors operating to produce and maintain the stripped zones at the edges of cliff-tops in favourable positions for development, include—

(a) chemical solution by rain-water;

(b) fritting by wind-driven media, including rain, sea-spray and occasionally small rock and mineral particles (e.g. quartz grains, small fragments of accretions, etc.);

(c) hydrostatic pressure of large breaking storm waves that reach heights of over 100 ft. on parts of the cliffs during severe tempests;

(d) abrasive action of water-borne sand, "buckshot gravel", and the harder portions of broken-off limestone (more especially pieces of the calcareous accretions). These are carried by (i) surface run-off waters flowing over exposed parts of the Post-Miocene Clay veneer which occurs at the landward fringe of practically all the stripped zones, below the zone of vegetation and soil, and (ii) by the surf thrown up from large breaking storm waves, which often pick up and move about any already dislodged accretions present.

The chemical factors involve a process of leaching, brought about by surface run-off waters composed largely of rain-water relatively low in salt concentration (from cyclic salts), but containing certain carbon dioxide compounds and hence possessing a pH value less than that of sea-water. This is capable of dissolving materials that would not pass into solution so readily if they were in constant contact with sea-water, the pH of which is approximately 7·5 to 8·4 (Sverdrup, Johnson and Fleming, 1942, p. 213). Under these conditions, the softer aphanitic limestone host tends to disintegrate more rapidly than the contained accretionary growths.

Mechanical factors involve traction of larger fragments of rock rubble during storms, when the impact of large breaking waves directed fully or obliquely against vertical to slightly backward-sloping, high cliff faces, causes large clumps and masses of sea-water and sea-spray to be thrown high up on to the edges of the cliff-tops; on receding, these, where sufficiently strong in their run-back, drag rock rubble over the limestone surface towards the cliff edges. At the same time, the effects of hydrostatic pressure of the large breaking waves, even at the greater heights, result in fracturing and ultimate dislodgement of some of the projecting accretions, and also the opening up of joint and bedding planes in the limestone.

The effects of alternate wetting by salt spray and drying out of the softer, more porous limestone matrix in places, assist in the disintegration of the limestone. This is partly evidenced by the occasional disruption of certain included fossils on crystallization of NaCl. The denser accretions are not so much affected by this process, although often observed to be encrusted with thin films of salt when dry. Subsidiary mechanical effects involve fritting by wind-driven media and abrasion by the smaller products of erosion transported across the stripped zones by surface run-off after rain.

Since the processes operating on the stripped zones are dominantly directed towards erosion, rather than precipitation, it is evident that the calcareous accretions in the Port Campbell Limestone are not being developed at the present time, in fact, under the prevailing conditions, the greater tendency is towards their destruction; all the evidence points rather to the accretions being syngenetic in origin.

Consequent Rock Sculpture

A feature of several of the stripped zones is the presence of shallow, basin-like depressions formed in the soft limestone (Pl. XXVIII, figs. G and H) between aggregates of accretionary growths. They result partly from solution, partly from local over-deepening by surface run-off waters, the sites of development being largely determined by the positions and degrees of exposure of the accretionary growth structures, which in large measure cause directed scour of the leached limestone. These depressions are often partially infilled with finer rock rubble, "buckshot gravel", sand and clay, which, when dry, sometimes reveal "mud-curls" on the surface (Pl. XXVIII, fig. H). A few of the depressions ultimately develop into small sink-holes. Others have been transected by landward cliff-edge recession, and their uncompacted infillings largely removed, thus revealing solution-abrasion pipes up to 20 and 30 ft. deep and 10 to 20 ft. in diameter.

Other features of the stripped zones are the variable pattern of accretions (Pl. XXVII, figs. A and B; Pl. XXVIII, fig. F), which help to determine the development of more resistant shelves (Pl. XXVII, fig. B) and small "outliers" composed of a protective capping of accretionary growth layers, set on pedestals of softer limestone more or less free of accretions (Pl. XXVII, fig. D). Some accretionary growths weather to bowl-like structures with honeycombed walls (Pl. XXVIII, fig. E); more rarely they appear as small ring-like structures (Pl. XXVIII, fig. F). Water overflowing from the perched bowl-like structures, occasionally develops small basin-like depressions in the softer host Port Campbell Limestone (Pl. XXVIII, fig. E) one to two ft. below the level of the edge of the bowl.

Where sufficiently concentrated in the limestone of the stripped zones, the accretionary growths dominate the minor features of local rock sculpture. Where situated lower down in the steep cliff faces, and hence more frequently attacked by the waves, concentrations of accretions arranged along horizontal planes, help to control the positions and size of notches (including visors), ledges and lower platforms. The wave-cut notches are in softer limestone or in calcareous clay situated sometimes above, sometimes below, occasionally between layers of accretions, while the ledges and platforms are frequently surfaced by accretionary growth layers. Weathered-out accretions lying on ledges, platforms and stripped zones, more particularly on the latter, often show grotesque and irregular shapes.

On one or two of the stripped zones located at approximately 100 ft. above sea level, occasional mounds up to 6 ft. high, consist of loose, irregularly-shaped blocks a foot or so across of limonitic accretionary growths; these are pronounced features at Gravel Point, 3 miles east of Port Campbell township. Originally formed as ferruginous accretions beneath the surface soils but above the Post-Miocene Clay veneer, they remain on top of the stripped zones longer, because of their larger size, their greater density and their more durable character compared with neighbouring and enclosing materials (lateritic soils and Post-Miocene Clay) which are fairly readily removed once the vegetation cover has been destroyed.

Owing to the combined effects of storm-tossed spray and limited stream channel flow of surface drainage along one or two parts of the Port Campbell Limestone Coastline, stripped zones are occasionally amphitheatre-like. The best-developed of this special type occurs at The Amphitheatre at the mouth of Ingle's Creek, 3¼ miles east of Port Campbell township, where the stripped zone is arcuate in plan, stepped in cross-sectional aspect, and is located some 50 ft. above normal sea level. It has thus been produced at the mouth of a small hanging valley, where marine erosion strongly dominates stream erosion. On the headlands, however, and elsewhere where hanging valleys are absent, the stripped zones normally trend parallel with relatively straight stretches of the cliff edges.

Stripped zones comparable in general characteristics and positions of development, also occur from place to place along the cliffed coastline constituted of similar sediments (Port Campbell Limestone), extending westwards from Peterborough to beyond Childers Cove on the southern coast of western Victoria.

References

Baker, G., 1943. "Features of a Victorian Limestone Coastline." *Journ. Geol.* LI; 359-86.

Sverdrup, H. V., Johnson, W. H., and Fleming, R. H., 1942. *The Oceans—Their Physics, Chemistry and General Biology.* Prentice-Hall, Inc., New York.

Description of Plates

Plate XXVII

Features of stripped zone some 30 to 40 yds. wide at seaward edge of cliff-top 60 ft. above sea level. East side of Broken Head, 4 miles south-south-east of Port Campbell, Victoria.

Fig. A.—General view showing calcareous accretions exposed as ragged projections from the softer Port Campbell Limestone matrix, and forming a craggy surface.

Fig. B.—Calcareous accretions forming more resistant shelf-like structures standing up to 3 ft. above the softer limestone. On further weathering, these shelves of layer-like accretions are stepped in parts and sometimes slightly overhanging.

Fig. C.—Numerous small, nodular calcareous accretions scattered through softer limestone matrix below the layer-like accretionary growths (match-box = 2 in. long).

Fig. D.—Small "outlier" of layered, bedding plane accretionary growths of calcium carbonate, capping a partially undercut pedestal of softer limestone. Undercutting of pedestal more marked on seaward side, while profile of pedestal slopes more gently in the erosion shadow on the landward (lee) side. Small, partially infilled basin at foot of pedestal on lee side.

Plate XXVIII

Features of stripped zone some 30 to 40 yds. wide at seaward edge of cliff-top 60 ft. above sea level. East side of Broken Head, 4 miles south-south-east of Port Campbell, Victoria.

Fig. E.—Bowl-like accretionary growth perched on pedestal, 2 ft. above general level of stripped zone. Rock rubble occurs in bowl-like structure, and small basin in softer limestone at foot of pedestal on down-drainage side (match-box = 2 in. long).

Fig. F.—Plan aspect of jagged and ring-shaped calcareous accretionary growths exposed some 2 to 3 in. above the level of the general surface of the stripped zone. Minor ridges in softer limestone at bottom right of photograph, represent the tops of emergent accretionary growth structures.

Fig. G.—Small basins 3 to 4 ft. across, developed in the softer limestone some 2 to 3 ft. below the level of calcareous accretions exposed on the surface of the stripped zone. Basins are partially infilled with rock rubble (mainly broken fragments of calcareous accretions, and "buckshot gravel") covered by fine sand and clay.

Fig. H.—"Mud-curls" resulting from desiccation and breaking up of superficial clay veneer into polygons, on top of partially infilled basin approximately 6 ft. long.